integration. Further than this, a meteoric stone would be less likely to attract the attention and curiosity of the ordinary individual than would an iron. So far as the first possibility is concerned, I think that all who have had to do with meteorite collections will agree that as a general rule the irons, through their susceptibility to a damp atmosphere and consequent rusting, require much more attention for their preservation than do the stones. The second possibility is, however, one that must be given consideration.

[1] See Chapter IV of Farrington's *Meteorites*, Chicago, 1915.

[2] The figures here given relative to number of falls are believed to be substantially correct up to 1916. Accurate statistics since that date are not available.

[3] It would be a natural supposition that the fall of an iron would be less noticeable than that of a stone since the former would be less liable to break up—explode—in its passage through the atmosphere. Unfortunately, the literature is not sufficiently explicit on this point to bear out the supposition. Hidden, to be sure, states that the fall of the Mazapil iron was accompanied only by a loud sizzing sound, there being no explosion or loud detonation. On the other hand, Kunz states that the fall of the Cabin Creek iron was "accompanied by a very loud report which caused the dishes to rattle," and the fall of the Nedagolla iron is also stated to have been accompanied by an explosion. Accounts of other falls are either noncommittal on this point or equally contradictory, and it is evident accurate information is lacking.

NOTE ON A CONTACT LEVER, USING ACHROMATIC DISPLACEMENT FINGERS

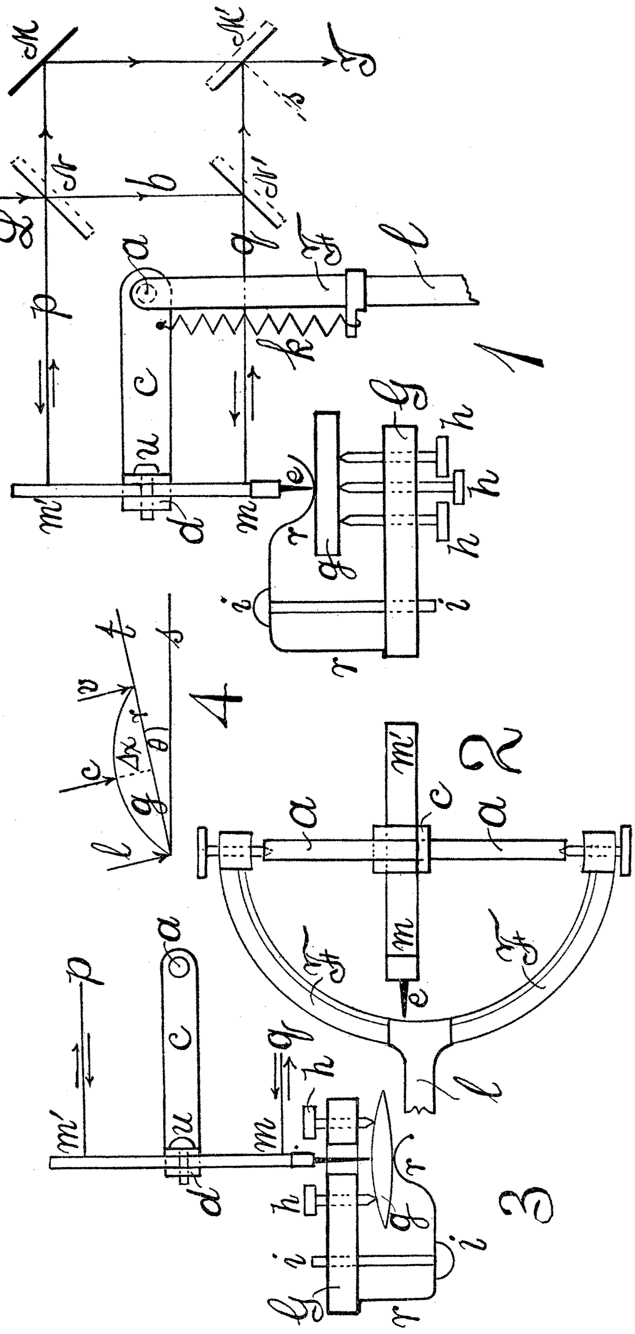
By Carl Barus

Communicated, December 27, 1918

1. Apparatus.—The method heretofore described for the measurement of small angles by the aid of the rectangular interferometer, lends itself conveniently for the construction of apparatus like the contact lever, or the spherometer. Having work needing such instruments in view, I designed the following simple apparatus for the purpose.

Figure 1 is a plan of the design; figure 2 an elevation of the fork and appurtenances; figure 3 (plan) finally shows the same apparatus adapted for use as a spherometer. The interferometer receives the white light from a collimator at L. After the reflections and transmissions controlled by the mirrors M, M', N, N', and the auxiliary mirror mm', as indicated in the figure, the light is conveyed into the telescope at T for observation of the interferences. The mirror M', is on a micrometer with the screw s normal to its face.

It is through the mirror mm' that the small angles are to be measured and this is therefore mounted at one end of the lever dc, capable of rotating around the long vertical axle aa, in the circular fork FF. The latter is rigidly mounted on the bed of the apparatus by aid of the stem l in the rear. The lever c is bent upward at right angles at d, and it is here that the mirror mm' is firmly



secured by bolts etc., as at *u*. The spring *k* draws the lever toward the front of the diagram, so that the blunt metal pin *e* suitably attached to the end of *mm'* may be kept in contact with the glass plate *g* to be tested.

The plate *g*, in order to be examined as to its degree of plane parallelism, must be capable of sliding up and down or right and left under standard conditions. To obtain these the stout bar *G* rigidly attached like *l* to the base of the apparatus, has been provided, carrying three set screws *h*, *h*, *h*, the points of which lie in the same circumference about 120° apart. They therefore constitute a kind of tripod against which the plate *g* is firmly pressed by the flat spring or clip *rr* and screw *i*. This method of mounting may be appropriately varied in accordance with the tests to be made on the plate *g*, its shape, etc. Similarly the set screws *h*, *h*, *h*, may be placed nearer together or further apart in appropriate screw sockets, and finally the lever *c* may be lengthened or shortened at pleasure. The pin *e* remains in permanent contact with the plate *g* in consequence of a wide circular hole in the clip *rr*; or *e* may clear *rr*, above or below it.

If but one face of the plate *g* is to be tested, the system *Ghrg* must slide as a whole right and left, nearly parallel to the rays *pq*. In such a case everything will depend on the excellence of the slide carrying the system. I did not attempt to make such arrangements, as I had no need of data of this kind; but parts *MM'*, *NN'*, *Fcmm'* and *Grg* were nevertheless mounted on heavy slides (lathe-bed fashion) for convenience in securing a variety of adjustments.

In figure 3 the bar *G* has been reversed in position and the contact pin *e* now passes through a circular hole in *G* to be in contact with a lens *g*, for instance, kept pressed to the tripod screws *h*, *h*, *h*, in the same way as before. The latter should in general be much closer together than the figure shows. The instrument is now a spherometer.

The experiments indicated that the mounting of the contact pin *e* to the extremity of the mirror *mm'* may be the occasion of annoyances. For on sliding *g* right and left or even up and down, the mirror *mm'* is liable to be flexed. In such a case the achromatic fringes rapidly lose sharpness, not to speak of the errors involved. I endeavored to avoid this by keeping the pin *e* out of contact with the plate *g* by a special lever (not shown), while *g* was being displaced and to test a number of successive contacts thereafter; but it is best to mount *e* on a *separate* rigid cross-piece parallel to *mm'* and firmly attached to *c*. In such a case no flexure of *mm'* can occur and the contacts may also be repeated at pleasure. Before each reading the bar *G* should be gently tapped.

The achromatic fringes can be found only through the spectrum fringes. This is not usually difficult remembering that not only must the slit images in the spectrum be in contact throughout, but the two beams must be locally in contact on the mirror *M'*. Moreover the mirrors *M'* and *N'* must be equally thick and the silvered faces all turned towards the auxiliary mirror *mm'*.

In the figures the contact lever *mme* is horizontal. It may also be mounted vertically but in such a case it is less easy to mount the mirrors M, M', N, N', when the system is to be exposed to tremors.

2. *Equations.*—If the mirrors M, M', etc., are set at an angle i, if the deflection of the auxiliary mirror is θ, and if the breadth of the ray parallelogram MM' or NN' is b, we may write

$$b\,\Delta\,\theta = \Delta\,N\cos i \tag{1}$$

where $\Delta\,N$ is the displacement at the micrometer at M'. If r is the length of the lever c figure 1 and $\Delta\,x$ the displacement of the pin e

$$r\,\Delta\,\theta = \Delta\,x \tag{2}$$

Hence

$$\Delta\,x = (r\cos i\,/\,b)\,\Delta\,N \tag{3}$$

Thus the apparatus is more sensitive as r is smaller and b is larger. In the instrument used (adapted from an earlier apparatus)

$$r = 11\text{ cm.};\; b = 10\text{ cm.};\; i = 45°$$

so that

$$\Delta x = .778\Delta N \tag{4}$$

But the main condition of sensitiveness is contained in the size of the fringes, and these may be made indefinitely large by suitable rotation of the mirrors M and M', for instance, in like direction on a horizontal axis (local coincidence of rays on M'). Since

$$2\Delta N\cos i = n\lambda$$

in case of the passage of n fringes, equation (3) becomes

$$\Delta x = nr\lambda/2b \tag{5}$$

Hence the limiting sensitiveness ($n = 10$) would be (with the above data)

$$\Delta x = 33 \times 10^{-6}\text{ cm.} \tag{6}$$

for a single fringe, a few tenths of which may be registered with certainty. When the achromatic fringes are used, it is however usually more convenient to *standardize* the ocular plate micrometer in the telescope, directly by aid of the screw micrometer at M', figure 1. If the ocular plate is divided in tenth millimeters along a centimeter of length and the fringes are of moderate size, one may estimate that about 40 scale parts correspond to $\Delta N = 10^{-3}$ cm. so that a single scale part of displacement of the achromatics is equivalent to $\Delta N = 25 \times 10^{-6}$ cm., while a few tenths of a scale part may here also be estimated.

If the apparatus (fig. 3) is to be used as a spherometer, the ordinary method of measuring from a plate of glass is at once available. If r is the radius of the circle of the tripod and Δx the height of the central foot, we obtain as usual for the radius R required

$$R = r^2/2\Delta x \tag{7}$$

This method gives good results for lenses of all curvatures, however strong, as the tests made indicated. But it is not necessary to use the plate to obtain a fiducial reading, provided the system *Gg* carrying the lens *g*, is on good right and left slides. For in figure 4, let θ be the angle between the plane of the tripod and the slides, and let three readings of ΔN be taken for three preferably equidistant points *l*, *c*, *v*, of the lens, by sliding *Gg* over equal distances, *r*. Let the reading be

$$y = N, \quad y' = N + r \tan\theta + \Delta N, \quad y'' = N + 2r\tan\theta \tag{8}$$

where ΔN corresponds to Δx in figure 4. Hence

$$2y' - (y + y'') = 2\Delta N$$

and equations (4) and (7) apply as before. This method also gives good results even for short distances, *r*.

3. *Observations.*—The use of the apparatus figure 1, with the strip of glass *g* to be tested sliding up or down, did not at first give satisfactory results, because the mirror *mm'* was too thin (2 mm. thick). It was found however, that on breaking contact at *c* during the sliding of *g* between successive positions or by gently tapping the bar or standard *G*, very fair results were obtainable. There would have been no difficulty in using a thick glass mirror *mm'* ($\frac{1}{4}$ inch or more) in which case the annoyance of flexure would have been negligible. But all difficulties were eliminated by using an independent arm to carry *e*, as stated above. Tapping at *G* before each observation is essential. The observations themselves must be omitted here. Tests of the degree of wedge-shape of long strips of glass from centimeter to centimeter of length, were made in detail, using both the screw and the ocular micrometer. Similarly, lenses of all focal lengths from a few centimeters to 100 cm. either convex or concave, were examined by the apparatus figure 3, with surprising ease and accuracy. The parts of the surfaces of such lenses may be explored to the fraction of a wave length, for successive circular patches of a cm. of radius, or less.

Finally the spherometer method of figure 4 and equation (8) gave entirely satisfactory results. An application for the measurement of (elastic) micrometric displacements will be discussed in a subsequent paper.